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13. ABSTRACT *(Maximum 200 words)*
An atlas of monthly mean global contour maps of albedo and absorbed solar radiation is presented for 21 months from November 1985 to October 1987. These data were retrieved from measurements made by the shortwave wide-field-of-view radiometer of the Earth Radiation Budget (ERB) instrument aboard the Nimbus 7 spacecraft. Profiles of zonal mean albedos and absorbed solar radiation were tabulated. These geographical distributions are provided as a resource for researchers studying the radiation budget of the Earth. The El Niño/Southern Oscillation event of 1986–1987 is included in this data set. This atlas of albedo and absorbed solar radiation extends to 12 years the period covered by two similar atlases: NASA RP-1230 (July 1975 to October 1978) and NASA RP-1231 (November 1978 to October 1985). These three compilations complement the atlases of outgoing longwave radiation by Bess and Smith in NASA RP-1185, RP-1186, and RP-1261, which were also based on the Nimbus 6 and 7 ERB data.

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Introduction

The solar radiation absorbed within the atmosphere and surface of the Earth provides the energy that moves the Earth's atmosphere and oceans and that governs our weather and climate (Hartmann et al. 1986). Absorbed solar radiation (ASR) is computed from the albedo at the "top of the atmosphere," which is computed from measurements, and from the incident solar radiation. The albedo and ASR depend on the surface properties of the Earth and clouds as well as the atmospheric transmissivity and reflectivity. The ASR varies spatially and temporally over a range of scales, from rapid local changes to large-scale fluctuations lasting months. The investigation of these slower fluctuations requires a data set of many years; this extended period also offers several opportunities to observe climatological events, such as the El Niño/Southern Oscillation (Philander 1990), and to provide a valid climatological mean.

To provide a long-term data set of radiation budget measurements at the top of the atmosphere, wide-field-of-view (WFOV) radiometers were part of the Earth Radiation Budget (ERB) instrument that was aboard the Nimbus 6 and 7 spacecraft. The ERB instrument began providing shortwave WFOV measurements from Nimbus 6 in July 1975 and from Nimbus 7 in October 1978 (Smith et al. 1977; Jacobowitz et al. 1984). Because those spacecraft were placed into orbits with near-noon equatorial crossings, their positions were ideal for measuring the albedo of the Earth at low and mid latitudes. Therefore, the data sets presented here are particularly interesting because the shortwave radiometers provide broadband measurements in a spectral range of 0.2 to 3.8 μm. Computations of broadband fluxes from narrowband instruments require extensive spectral corrections; however, the corrections themselves introduce errors. The present measurements do not require such extensive corrections, thus are inherently more accurate. Also, the Nimbus 7 ERB WFOV radiometers have consistently provided data from a single instrument since 1978.

Because WFOV radiometers have such a large field of view, a method of retrieving the albedo distribution was developed that enhances radiometer resolution (Smith and Rutan 1990). The Nimbus 6 and 7 ERB data from July 1975 to October 1985 were analyzed with this technique, and the results were compiled in two atlases (Smith, Rutan, and Bess 1990a, 1990b). The outgoing longwave radiation has likewise been analyzed and documented (Bess and Smith 1987a, 1987b).

Nimbus 7 ERB Project personnel at the Goddard Space Flight Center have recently processed measurements from November 1985 to October 1987. In this compilation, the resulting shortwave measurements are analyzed to produce resolution-enhanced maps of monthly averaged albedo and ASR. This paper presents an atlas of these maps; when combined with the previously published atlases, these three atlases cover a 12-year span. Bess and Smith (1991) used the corresponding longwave measurements to produce monthly mean maps of outgoing longwave radiation for this period in a companion paper. Nimbus 7 ERB data from 1985 to 1987 are especially useful because they are partially contiguous in time with the data from the Earth Radiation Budget Experiment (ERBE) scanning and nonscanning radiometers aboard the National Oceanic and Atmospheric Administration (NOAA) 9 and 10 spacecraft and the dedicated Earth Radiation Budget Satellite. Thus, the data can be used for comparison and validation studies.

Data Processing and Analysis

From October 1985 to September 1987, the ERB instrument operated continuously except for short periods, when it was on a duty cycle of 3 days on and 1 day off. This duty cycle was used early in the Nimbus 7 mission to conserve power, but that approach did not seriously degrade the results (Bess and Smith 1987a, 1987b; Smith, Rutan, and Bess 1990b). However, power limitations did preclude ERB measurements from April 10 to June 23, 1986. Thus, April, May, and June 1986 are missing from this set.

When the ERB instrument is on, WFOV measurements are taken at 4-second intervals. Four consecutive measurements are averaged to produce one value every 16 seconds. The data consist of these 16-second averages together with the time, latitude, and longitude for each measurement. Kyle et al. (1990) describe the data processing to account for instrument degradation.

Monthly maps of albedo were computed from the shortwave WFOV radiometer measurements based on Smith and Rutan's retrieval method (1990). Also, Smith, Rutan, and Bess (1990b) discuss their additional application of the method to 7 years of Nimbus 7 ERB measurements. First, monthly average maps of the measurements are compiled in a 5° by 5° grid. Then, the albedo map that corresponds to this measurement map is computed. The albedo field A is expressed as a Fourier series in longitude as

$$A(\theta, \Phi) = \sum_{n=-N}^{N} \exp(i\ n\ \Phi)\, f_n(\theta)$$

where θ and Φ are the colatitude and longitude of a point, i is the square root of -1, and N is the number of Fourier terms in longitude. The $f_n(\theta)$ terms are also computed as a series, with the coefficients determined from the measurements.

The numbers of terms that can be retrieved for each $f_n(\theta)$ to describe the albedo distributions determine the latitudinal resolution of the resulting distribution. These numbers depend on the space and time sampling errors for the average map and are listed in table I for each month in the data period. For wave number 0 (i.e., the zonal average), 28 to 34 terms are retrievable, which provides a latitudinal resolution better than 10°. Although measurements are averaged into 5° longitude grid boxes, Rutan and Smith (1991) have shown that, because of space and time variability and corresponding sampling problems, better results for monthly mean maps are obtained by retaining only 12 Fourier waves in longitude, which is equivalent to 15° longitudinal resolution.

The albedo cannot be unambiguously computed near the terminator from WFOV measurements. The limits of observability given by Smith and Rutan (1987) and Smith, Rutan, and Bess (1990b) for the Nimbus 7 orbit depend on time of year. The ASR is the product of albedo and solar insolation. Thus, even though the albedo error increases near the terminator, the insolation decreases more rapidly than the albedo error increases, and the ASR error also decreases.

Results

This atlas contains monthly mean maps of albedo and ASR from November 1985 to October 1987, excluding April, May, and June 1986; the data were computed from Nimbus 7 shortwave WFOV measurements. The albedo maps (at the back of this report) show contours with intervals of 5 percent. Dotted lines indicate albedos less than 30 percent. Because of the limitations of albedo results retrieved from WFOV measurements, the resolution is limited to 10° in latitude and 15° in longitude. At high latitudes the results are based on a priori data. The ASR maps show contours with intervals of 25 W/m^2, with contours of 250 W/m^2 or greater given as dotted lines. Table II lists the mean zonal averages of albedo for 5° latitudinal widths for each month of the period.

The nearly 2 years of albedo and ASR maps in this atlas, combined with the ASR data sets of Smith, Rutan, and Bess (1990a, 1990b), completes a 12-year data set of albedo and ASR. Thus, for each January, 12 realizations are among the three atlases. The standard deviation of the ASR for January about the mean is a measure of the interannual variability of the ASR and is shown in figure 1. Figures 2 to 12 reflect the same treatment for the remaining months. The strongest interannual variations occur in the tropics and subtropics from January to March; these variations are associated with the El Niño/Southern Oscillation (ENSO) climatological events. These ENSO events occurred during the northern winters of 1977–1978, 1982–1983, and 1986–1987. The present 2-year data set thus contributes another ENSO event to the ASR record.

Concluding Remarks

Geographical distributions of albedo and absorbed solar radiation are presented here as a resource for researchers studying the radiation budget of the Earth. This atlas of shortwave data extends to 12 years and comprises the absorbed solar radiation data set from the Earth Radiation Budget (ERB) wide-field-of-view (WFOV) radiometers aboard the Nimbus 6 and 7 spacecraft reported by Smith, Rutan, and Bess in 1990. This compilation complements the atlases of outgoing longwave radiation based on Nimbus 6 and 7 WFOV measurements analyzed by Bess and Smith in 1987 and 1991.

The last 3 years are particularly interesting because, during this time, the Earth Radiation Budget Experiment (ERBE) was also operating, thereby providing an excellent opportunity for comparison and validation studies. Also, the El Niño/Southern Oscillation event of 1986–1987 occurred during this period.

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Table I. Number of Singular Vectors Used To Describe Each Fourier Longitudinal Wave Number

Month	Number of singular vectors for wave number of—											
	0	1	2	3	4	5	6	7	8	9	10	11
Nov. 1985	30	30	26	26	26	20	12	12	6	6	4	4
Dec. 1985	28	28	26	26	24	24	14	14	10	6	2	2
Jan. 1986	32	30	28	28	24	24	12	8	4	2	2	2
Feb. 1986	30	30	26	16	16	16	10	10	10	4	4	4
Mar. 1986	30	30	24	24	24	24	10	10	4	4	4	4
Apr. 1986												
May 1986												
Jun. 1986												
Jul. 1986	30	30	30	22	14	14	12	12	6	6	4	4
Aug. 1986	30	30	28	18	18	18	6	6	6	6	2	2
Sep. 1986	30	30	28	22	22	18	14	12	12	8	2	2
Oct. 1986	36	32	28	10	10	10	4	4	4	4	2	2
Nov. 1986	30	30	30	18	18	16	16	8	4	2	2	2
Dec. 1986	30	30	30	28	28	28	14	14	8	8	2	0
Jan. 1987	32	30	28	28	20	16	14	10	10	2	2	2
Feb. 1987	30	30	30	24	20	20	14	14	6	6	6	6
Mar. 1987	30	30	30	28	26	10	8	4	4	2	2	2
Apr. 1987	30	30	26	26	26	26	14	14	8	8	4	4
May 1987	30	30	30	30	28	28	14	14	14	14	8	8
Jun. 1987	30	30	30	26	26	26	14	14	8	8	4	2
Jul. 1987	30	30	30	28	28	28	14	14	10	10	10	10
Aug. 1987	32	30	30	28	26	24	12	12	8	4	4	4
Sep. 1987	30	30	30	26	26	26	10	10	6	6	2	2
Oct. 1987	34	34	32	30	26	26	12	12	12	8	4	4

Table II. Zonal Albedo Means for 1985 to 1987

(a) November 1985 to October 1986

Table II. Concluded

(b) November 1986 to October 1987

Figure 1. Standard deviation of absorbed solar radiation about monthly mean for January.

Figure 2. Standard deviation of absorbed solar radiation about monthly mean for February.

Figure 3. Standard deviation of absorbed solar radiation about monthly mean for March.

Figure 4. Standard deviation of absorbed solar radiation about monthly mean for April.

Figure 5. Standard deviation of absorbed solar radiation about monthly mean for May.

Figure 6. Standard deviation of absorbed solar radiation about monthly mean for June.

Figure 7. Standard deviation of absorbed solar radiation about monthly mean for July.

Figure 8. Standard deviation of absorbed solar radiation about monthly mean for August.

Figure 9. Standard deviation of absorbed solar radiation about monthly mean for September.

Figure 10. Standard deviation of absorbed solar radiation about monthly mean for October.

Figure 11. Standard deviation of absorbed solar radiation about monthly mean for November.

Figure 12. Standard deviation of absorbed solar radiation about monthly mean for December.